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(71) Applicant *(for all designated States except US)*: **OTB GROUP B.V.** [NL/NL]; Luchthavenweg 10, NL-5657 EB Eindhoven (NL).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **MISCHKE, Wlodek, Stanislaw** [NL/NL]; Pinkelbergen 15, NL-5683 LN Best (NL). **VAN ASSCHE, Ferdinandus, Josephus, Honoré** [NL/NL]; Boutenslaan 71, NL-5644 TS Eindhoven (NL). **DINGS, Franciscus, Cornelius** [NL/NL]; Regulus 26, NL-5505 TD Veldhoven (NL). **VANGHELUWE, Rik, Theodoor** [NL/NL]; Landjuweel 7, NL-5571 ML Bergeijk (NL). **KESSELS, Wilhelmus, Mathijs, Marie** [NL/NL]; Bijsterveldenlaan 13, NL-5045 ZZ Tilburg (NL). **VAN DE SANDEN, Mauritius, Cornelis, Maria** [NL/NL]; Jan van Beverwijckstraat 39, NL-5017 JC Tilburg (NL).

(74) Agent: **WINCKELS, J.H.F.**; Nieuwe Parklaan 97, NL-2587 BN Den Haag (NL).

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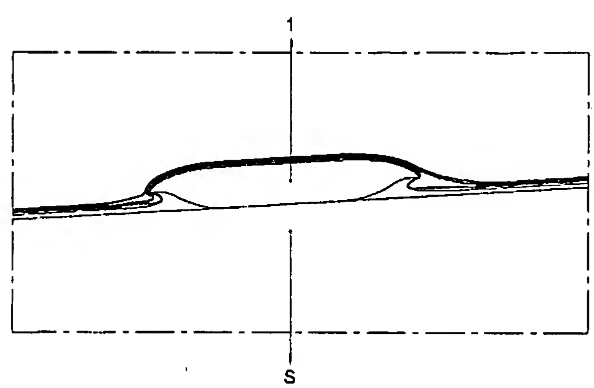
(54) Title: METHOD FOR APPLYING A THIN FILM BARRIER STACK TO A DEVICE WITH MICROSTRUCTURES, AND DEVICE PROVIDED WITH SUCH A THIN FILM BARRIER STACK



(57) Abstract: A method for applying a thin film barrier stack to a device with microstructures, such as, for instance, an OLED, wherein the thin film barrier stack forms a barrier to at least moisture and oxygen, wherein the stack is built up from a combination of organic and inorganic layers, characterized in that a first organic intermediate layer is applied, wherein the organic intermediate layer is applied in liquid form, wherein the viscosity of the organic intermediate layer liquid is so low that grooves, hollows and like narrow cavities are at least partly filled up with the organic liquid under the influence of capillary forces while other parts of the device are only covered with a thin layer of the organic liquid, such that a layer of variable thickness is formed.

WO 2005/015655 A1

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Title: Method for applying a thin film barrier stack to a device with microstructures, and device provided with such a thin film barrier stack

This invention relates to a method for applying a thin film barrier stack to a device with microstructures, such as, for instance, an OLED, wherein the thin film barrier stack forms a barrier to at least moisture and oxygen, and wherein the stack is built up from a combination of organic and inorganic layers.

Such a method is known, for instance, from US 6,413,645 or DE 196 03 746 A1.

Devices to which the thin film barrier stacks are applied, can be, for instance, OLED's, which are described, for instance, in US 6,582,888 B1.In the known method for applying a thin film barrier stack, on the microdevice, first a relatively thick levelling layer is applied over the device in order to facilitate the application of consecutive layers forming the actual barrier against oxygen and moisture. Specifically in devices where the microstructures include undercut regions, as is the case, for instance, with mushroom structures on OLED's, this smoothing layer should have a considerable thickness. The disadvantage of first having to apply a thick levelling layer over the device is that moisture and oxygen may still penetrate to the device from the side and that air inclusions may arise between the active layers of the device and the relatively thick levelling layer. Moreover, such thick polymeric levelling layers easily give rise to delamination, which results in loss of the device. In devices which are provided with microstructures having sharp angles, steep or even negative inclinations and undercut regions, such as, for instance, OLED's provided with mushroom structures, it is a problem to apply a sealing inorganic layer of a sufficient layer thickness over the entire surface, that is, also in the undercut regions.

The object of the invention is to provide a method for manufacturing an encapsulation layer for a device which is provided with microstructures, wherein the encapsulation layer comprises a thin film barrier stack which is built up from a combination of organic and inorganic layers and wherein the above-described disadvantages of the known encapsulation layers are solved.

To that end, the invention provides a method of the type described in the opening paragraph hereof, which is characterized in that a first organic intermediate layer is applied, wherein the organic intermediate layer is applied in liquid form, wherein the viscosity of the organic intermediate layer liquid is so low that grooves, hollows and like narrow cavities are at least partly filled up with the organic liquid under the influence of capillary forces while other parts of the device are only covered with a thin layer of the organic liquid, such that a layer of variable thickness is formed.

According to the invention, a thin organic layer is applied in liquid form and the cavities fill up at least partly with the organic liquid under the influence of capillary forces while the other parts of the device are only covered with a very thin layer of the organic liquid. Thus, possible continued growth of pin holes in inorganic layers is prevented. In that way, optionally in a number of steps a complete fill-up of the cavities can be achieved without the organic layer assuming such a thickness as to tend to delamination. Due to the organic layer moreover being very thin compared to the known levelling layers, the chance of air inclusions in the layer is much lower. Preferably, the amount of liquid applied is such that the thickness of the thin layer covering the said other parts is smaller than 0.5 μm, more preferably smaller than 0.1 μm. Preferably, the viscosity of the organic intermediate layer liquid is lower than 100 cP, more preferably lower than 20 cP and even more preferably lower than 10 cP.

According to a further elaboration of the invention, first a first sealing inorganic layer is applied before the first organic layer is applied.

Thus, the functional layers of the device are already protected from moisture and oxygen by the first sealing inorganic layer, so that if there might be any air inclusion present in the first organic layer after all, this would be much less harmful to the functional layers of the device. Since upon application of the organic layer the undercut regions, the grooves, hollows or like cavities have been partly filled up, the device will already have a more level surface, so that an inorganic layer to be subsequently applied will obtain a more stable structure and hence will form a better sealing. When subsequently, in the same manner as described above, once more an organic layer in liquid form of low viscosity is applied, a still further smoothing of the microstructures is obtained and an inorganic layer to be subsequently applied will have even more stable and better sealing properties.

The organic liquid can be applied, for instance, by means of spin coating, spraying, dipping, condensation, inkjet printing or wedge coating. In addition, the organic liquid may be strongly diluted in a solvent in order to obtain a low viscosity. To be considered here is a viscosity comparable to that of water, so that the capillary forces will in fact lead to local layer thickness differences in the organic layer.

After applying the layer, the solvent should at least partly be removed from the organic layer, after which the organic layer is polymerized or otherwise hardened. The polymerization or hardening can take place in a known manner by means of UV irradiation, electron or ion irradiation, thermally, chemically, or in a like manner.

The first sealing layer can be a ceramic conformal layer. It is also possible, however, to apply a non-conformal layer. The inorganic layers, among which the first inorganic sealing layer, may be manufactured from transparent and non-transparent ceramic materials, such as metal nitrides,

metal oxides, metal oxynitrides, metal carbides, metal oxyborides or combinations thereof. Metals to be considered by way of example are aluminum, silicon, boron, zirconium, titanium, hafnium, tantalum, niobium and tungsten.

The first encapsulation layer can be applied, for instance, by vacuum deposition, such as, for instance, PVD, PECVD or the like. The organic intermediate layers applied in liquid form can contain polymer, such as, for instance, acrylate, epoxy, fluoropolymer, ppx, organosilicons and the like. Other polymers may also be applied. Other examples are mentioned in the American patent US 6,413,645 B1, mentioned earlier.

After applying a number of combinations of an inorganic and an organic layer, it is preferred, according to a further elaboration of the invention, that further a last inorganic layer is applied for screening the uppermost organic layer from the external world. It is also possible, however, that an organic layer forms the last layer of the thin film barrier stack.

The invention further relates to a device provided with microstructures provided with a thin film barrier stack manufactured by a method according to the invention. According to a further elaboration of the invention, the device can be an organic light emitting diode (OLED), the OLED being provided with a microstructure comprising mushroom structures.

The invention will presently be further clarified on the basis of an exemplary embodiment with reference to two photographs.

Fig. 1 shows a cross section of a portion of an OLED; and

Fig. 2 shows a detail of the photograph shown in Fig. 1.

Fig. 1 shows a portion of an OLED device, where a mushroom structure 1 is arranged on a substrate S. The mushroom structure 1 provides undercut regions which make it possible, using a vertical deposition technique, to provide conductive paths on the substrate S which

are interrupted in the undercut regions of the mushroom structure. Under these conductive paths, functional layers 2 have been provided, which, in the present case, have light emitting properties. These functional layers 2 are highly sensitive to moisture and oxygen and must therefore be screened from the environment. That is the purpose served by the thin film barrier stack which, in the present exemplary embodiment, is built up from three inorganic layers 3, 5, 7 and two organic layers 4, 6. Specifically in the detail of Fig. 2, it is clearly visible that the polymeric, organic layers 4, 6 do not have the same thickness throughout, but are considerably thicker in the undercut region under the mushroom structure 1. This is the result of the fact that the organic layer has been applied in liquid form, while the viscosity of the liquid has been chosen to be very low, such that capillary forces prevailing in the narrow space under the mushroom structure cause liquid to accumulate there. Clearly visible in Fig. 2 is that the undercut region, after application of two polymeric layers, is filled up completely and that no undercut region is present anymore. According as the course of the ceramic layers is more gradual - the ceramic layer designated by reference numeral 7 having a very gradual course without sharp bends therein - the stability of such a layer is greater. As, moreover, the polymeric layers are very thin, the chance of delamination is particularly low. Only in the regions where some thickness is required for filling up hollows, grooves and like narrow cavities, this extra thickness is obtained automatically owing to the application of the organic layer in liquid form of low viscosity.

After applying an organic layer, the solvent is evaporated therefrom, after which the layer is hardened in the manner as described above. After hardening of an organic layer, a ceramic layer can be applied using the techniques already mentioned hereinabove.

Before applying the first organic layer in liquid form, the device is first protected with a first ceramic layer 3. This prevents the functional layer 2 being possibly damaged under the influence of the liquid organic

layer. Moreover, any air inclusions in the organic layer, which, for that matter, will hardly occur because of the very minor thickness of the organic layer, are less likely to have an adverse effect on the functional layers 2 because the latter have already been screened with the first ceramic layer 3. In order to accomplish a good protection of the last-applied organic layer 6, the last-applied layer of the thin film barrier stack is formed by a ceramic layer 7 that is moisture and oxygen tight.

It will be clear that the invention is not limited to the exemplary embodiment described. Other devices can also be suitably provided with a thin film barrier stack. To be considered in this regard are, for instance, chips, LCD's, and like devices that are provided with microstructures with sharp angles, steep or even negative inclinations and undercut regions.

CLAIMS

1. A method for applying a thin film barrier stack to a device with microstructures, such as, for instance, an OLED, wherein the thin film barrier stack forms a barrier to at least moisture and oxygen, wherein the stack is built up from a combination of organic and inorganic layers, characterized in that a first organic intermediate layer is applied, wherein the organic intermediate layer is applied in liquid form, wherein the viscosity of the organic intermediate layer liquid is so low that grooves, hollows and like narrow cavities are at least partly filled up with the organic liquid under the influence of capillary forces while other parts of the device are only covered with a thin layer of the organic liquid, such that a layer of variable thickness is formed.

2. A method according to claim 1, wherein first a first sealing inorganic layer is applied before the first organic layer is applied.

3. A method according to claim 1 or 2, wherein the organic liquid is applied by means of spin coating, spraying, immersion, condensation, inkjet printing or wedge coating.

4. A method according to any one of claims 1-3, wherein the organic liquid is strongly diluted in a solvent in order to obtain a low viscosity.

5. A method according to claim 4, wherein the solvent, after application of the layer, is at least partly removed from the organic layer through evaporation.

6. A method according to claim 5, wherein after the at least partial removal of the solvent from the organic layer, this organic layer is polymerized and/or hardened.

7. A method according to claim 6, wherein the polymerization and/or hardening is/are carried out by means of UV irradiation, electron or ion irradiation, thermally, chemically, or in a like manner.

8. A method according to any one of the preceding claims, wherein the inorganic layer is a ceramic conformal layer which substantially follows the contours of the microstructures of the device.

9. A method according to any one of the preceding claims, wherein the first sealing layer is a ceramic layer, such as, for instance, a layer from metal nitrides, metal oxides, metal oxynitrides, metal carbides, metal oxyborides or combinations thereof.

10. A method according to claim 9, wherein the metal is aluminum, silicon, boron, zirconium, titanium, hafnium, tantalum, niobium or tungsten.

11. A method according to any one of the preceding claims, wherein the first sealing layer is applied through vacuum deposition, such as, for instance, PVD, PECVD or the like.

12. A method according to any one of the preceding claims, wherein the organic intermediate layer which is applied in liquid form contains a polymer, such as, for instance, acrylate, epoxy, fluoropolymer, ppx, organosilicons and the like.

13. A method according to any one of the preceding claims, wherein after applying a first inorganic layer and an organic layer in the above-described manner, further at least one next combination of an inorganic and an organic layer is applied in a manner as described with reference to the first inorganic and the first organic layer.

14. A method according to claim 13, wherein after applying the last combination of an inorganic and organic layer, additionally a last inorganic layer is applied for sealing the uppermost organic layer from the external world.

15. A method according to any of the preceding claims, wherein the viscosity of the organic intermediate layer liquid is lower than 100 cP, more preferably lower than 20 cP, even more preferably lower than 10 cP.

16. A method according to any of the preceding claims, wherein the amount of liquid applied is such that the thickness of the thin layer covering the other parts is smaller than 0.5 µm, more preferably smaller than 0.1 µm.

17. A device provided with microstructures provided with a thin film barrier stack manufactured according to a method according to any one of the preceding claims.

18. A device according to claim 17, wherein the device is an organic light emitting diode (OLED).

19. A device according to claim 18, wherein the OLED is provided with a microstructure comprising mushroom structures.

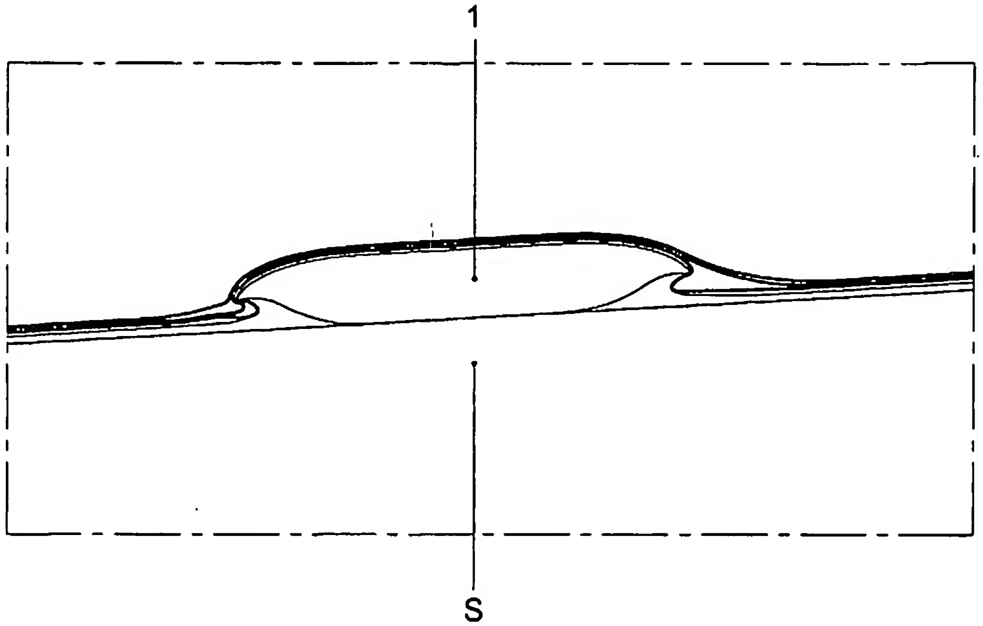

Fig. 1

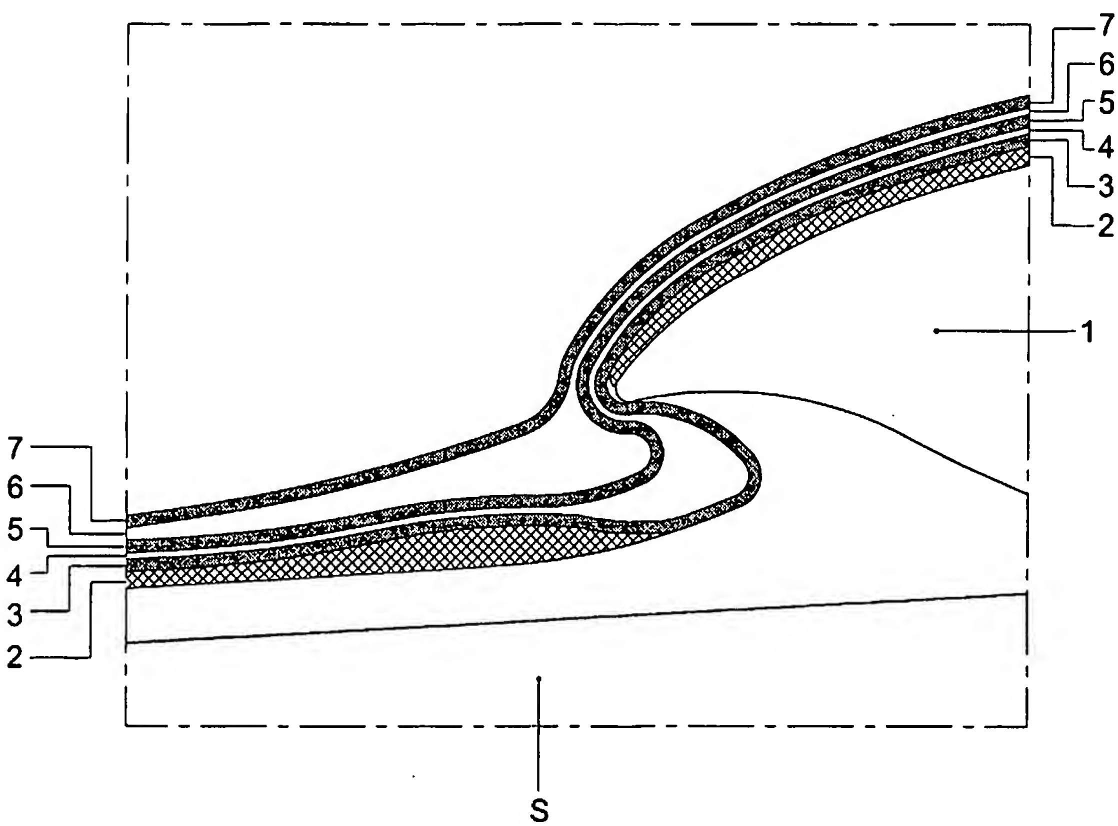

Fig. 2

INTERNATIONAL SEARCH REPORT

International Application No
PCT/NL2004/000563

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01L51/20

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H01L H05B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No
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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
17 January 2005	24/01/2005

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	van der Linden, J.E.

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
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